EFFECT OF SOIL RESISTIVITY IN PEKAN CAMPUS TO THE CORROSION BEHAVIOR OF STEEL PIPE SYSTEM

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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

To my beloved parents, Mr. Ahmad Sani Bin Othman and Mrs. Noor Asiah Bte. Hussin, family and friends, without whom and his/her lifetime efforts, my pursuit of higher education would not have been possible and I would not have had the chance to study for a mechanical course. Also to my supervisor, Mrs. Dayangku Noorfazidah Bte. Awang Shri and Faculty of Mechanical Staff, without whose wise suggestions, helpful guidance and direct assistance, it could have neither got off the ground nor ever been completed. Thanks a lot to my university and my friends in their support and advice towards this project. Thanks to all for your enduring patience and continuous encouragement.

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ABSTRACT

Underground pipe system will place at different place and will pass through the different soil structure. This different soil condition has different soil resistivity that will give the different result of the corrosion rate at same pipeline system. In this experiment, soil resistivities of different type of soils were measured by using Earth Resistance Tester. It is found that the soil resistivity of sand is the lowest at 5.03 kΩ·cm and followed by clay and loam with 94.25 kΩ·cm and 628.32 kΩ·cm respectively. The effect of soil resistivity on corrosion behavior of coated and uncoated specimen were examined by buried the specimen in three different type of soil for 50 days. The surface morphology were examined by using SEM while corrosion rate was calculated using weight loss. Surface morphology examinations indicate the type of corrosion occurred on the steel pipe was uniform corrosion, erosion corrosion and pitting corrosion. It is found the corrosion rate is highest in sand followed by clay, loam and atmosphere. It is also found that coating has decreased the corrosion rate of the specimen with highest at sand which 6.76 mpy followed by clay, loam and atmosphere with 6.36, 5.88 and 1.52 mpy respectively.In conclusion, with the lower soil resistivity, the corrosivity of the steel pipe will be higher. It is also found that coating specimen proves that it can reduce the corrosion rate of the pipeline system.

ABSTRAK

Sistem paip bawah tanah yang diletakkan di tempat yang berbeza dan akan melewati struktur tanah yang berbeza. Keadaan tanah ini mempunyai rintangan tanah yang berbeza mengikut jenis tanah yang akan memberikan keputusan kadar kakisan yang berbeza pada sistem paip yang sama. Dalam kajian ini, rintangan tanah diukur dengan menggunakan "Earth Resistance Tester" bagi menentukan kadar rintangan yang terjadi pada pelbagai jenis tanah. Rintangan tanah yang di hitung menunjukkan tanah pasir mempunyai rintangan lebih rendah dengan 5.03 kΩ·cm diikuti dengan tanah liat dan tanah lempung dengan masing- masing 94.25 kΩ·cm dan 628.32 kΩ·cm. Kesan rintangan tanah terhadap perilaku kakisan untuk besi yang dilapisi cat dengan tidak dilapisi dilakukan dengan menanam besi kajian di tiga jenis tanah yang berlainan selama 50 hari. P emeriksaan permukaan morfologi dilakukan dengan menggunakan SEM sementara kadar kakisan dikira dengan menggunakan kaedah berat badan besi. Permukaan pemeriksaan morfologi menunjukkan jenis kakisan berlaku pada paip baja korosi seragam, korosi berombak dan korosi berlubang. Kadar kakisan tertinggi ditemui terjadi pada besi yang di tanam di tanah pasir diikuti oleh tanah liat, lempung dan atmosfera. Didapati juga besi yang dilapisi dapat menurunkan kadar kakisan dengan besi yang tertinggi di tanam pada tanah pasir dengan 6.76 mpy yang diikuti oleh tanah liat, lempung dan atmosfera dengan masing-masing 6.36, 5.88 dan 1.52 mpy. Sebagai kesimpulan, rintangan tanah yang lebih rendah akan meningkatkan kadar kakisan pada spesimen besi ujikaji. Dari projek ini juga, dapat dibuktikan bahawa kadar kakisan dapat dikurangkan dengan menggunakan spesimen besi yang dilapisi cat untuk paip sistem.

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LIST OF SYMBOLS

cm	Centimeter
°C	Degree Celsius
g /cm³	Density
g	gram
I	Impressed current
m	Meter
mm	Milimeter
mpy	mils per year
Ω	Ohm
%	Percentage
V	Potential Energy or Voltage
Ω/cm	Soil Resistivity

LIST OF ABBREVIATIONS

e^-	Electron
A	Surface Area
AC	Alternating current
ASTM	American Standard Testing Method
CL	Chloride
D	Density
DC	Direct current
Fe	Ferrous
H	Hydrogen
HCL	Hydrochloric Acid
SEM	Scanning Electron Microscope
T	Time
W	Weight Loss in grams

CHAPTER 1

INTRODUCTION

1.1 Introduction

Corrosion is defined in different ways, but the usual interpretation of the term is “an attack on a metallic material by reaction with its environment”. Corrosion is natural and inevitable, but it can be minimized and delayed. This concept of corrosion can be used in a broader sense, where this includes attack on nonmetallic materials. For example, the response of steel to soil corrosion depends primarily on the nature of the soil and certain other environmental factors, such as the availability to moisture and oxygen. These factors can lead to extreme variations in the rate of the attack. So this project is to effect of Soil Resistivity to the corrosion behavior of steel pipe system. By following the useable concept of the corrosion mechanism, it is easier to understand various conditions to be that which cause active corrosion on steel pipe in soil.

1.2 Background of study

The resistivity of a soil is probably the most commonly used criterion of corrosivity because it is easy to measure. The resistivity of a soil depends on its chemical content, moisture content and temperature. Low-resistivity soils for instance generally contain high concentrations of soluble salts. The presence of anions in the salt degrades protective oxide films on steel accelerating the rate of the electrochemical reactions at the metal surface.

Since macrocells are responsible for many of the instances of severe corrosion of underground structures, the expectation a correlation to exist between soil moisture content and underground corrosion. Such correlations are found in the literature. For example, researcher found that only resistivity and redox potential were better predictors of corrosiveness than moisture content. Data showing the effect of salt content which is chlorides and sulfates on the resistivity of single salt solutions are also found. The data show a systematic trend of decreasing resistivity with an increasing concentration profile for sulfate and chloride solutions.

A wide variety of soluble salts are typically found in soils. In fact two soils having the same resistivity may have significantly different corrosion characteristics, depending on the specific ions available. The major factors that accelerate corrosion are chlorides, sulfates, and the soil acidity (pH). In many areas soils encountered along a pipeline route will be approximately neutral with 7 pH value. Mild steel is widely used in pipes buried in soil. The corrosion of such metallic materials leads to numerous problems concerning for example water supply systems and soil pollution by ferric ions.

Laboratory investigations are highly important but require knowledge of the physical and chemical properties of the soil which can be affected by many factors particularly by changes in the nature of soil.

Actually, steel in deareated, dry soil should not corrode at all but must soils are not dry. Soil resistivities are an indication that moisture and dissolved salts are present and the corrosivity of soil is almost proportional to the decrease in resistivity. (S. Arzola, 2003)

1.3 Problem statement

Pipelines play an extremely important role throughout the world as means of transporting gases and liquids over long distances from their sources to the ultimate consumers. Pipelines suffer from corrosion, cracking and other problems. External corrosion has been recognized for many years as one of the main deterioration mechanisms that may reduce the structural properties of buried transmission pipelines (M. A. Alodan, 2007). The resistivity of soil also can corrode the steel pipe. But by monitoring the corrosive soil environment it will help to prevent catastrophic failure.

Nowadays there are many probe and soil corrosion rate monitor. With a low cost investment it will represent significant savings of the high cost of pipeline failure.

Underground pipelines will pass through the different soil structure and different soil conditions have different resistivity that will affect the corrosion rate of the same pipe at different place. Other structures are often the result of differential corrosion cells of which a variety of different types exist. These include differential aeration cells where different parts of a pipe are exposed to different oxygen concentrations in the soil and cells created by differences in the nature of the pipe surface or the soil chemistry. Galvanic corrosion is a form of differential cell corrosion in which two different metals are electrically coupled and exposed in a corrosive environment. These all are the corrosion behavior that usually happen at pipe in soil. (M. A. Alodan, 2007)

1.4 Project objectives

The goal of this study was to evaluate the effect of Soil Resistivity in Pekan Campus to the corrosion behavior of steel pipe system. This project enhances a student ability to work individually. The objectives of this project are:

i. To investigate the effect of soil resistivity to the corrosion behavior of steel pipe system.
ii. To analyze the corrosion type occurs to the steel pipe system.
iii. To determine the corrosion rate of pipe system by using weight loss method.
iv. To determine the changes of surface of steel pipe using Scanning Electron Microscope (SEM).
v. To evaluate the effect of coating on different soil resistivity.

1.5 Project scopes

This project is aim to evaluate the effect of soil resistivity on corrosion behavior on steel pipe. The scopes of the project are:-

i. Steel pipe dimension is 80 mm length, 22 mm inner diameter and 26 mm outer diameter.
ii. Analysis the soil resistivity using Earth Resistance Tester.
iii. Performing the exposure of mild steel pipe for 50 days.
iv. Analysis of corrosion rate based on weight loss method.
v. Surface morphology investigating using Scanning Electron Microscope (SEM).

CHAPTER 2

LITERATURE STUDY

2.1 Introduction

To view corrosion engineering in its proper perspective, it is necessary to remember that the choice of a material depends on many factors, including its corrosion behavior. Figure 2.1 shows some of the properties that determine the choice of a structural material. Although primarily concerned with the corrosion resistance of various materials the final choice frequently depends on factors other than corrosion resistance. The engineering aspects of corrosion resistance cannot be overemphasized. Complete corrosion resistance in almost all media can be achieved by the use of either platinum or glass but these materials are not practical in most cases. (Mars G. Fontana, 1986)

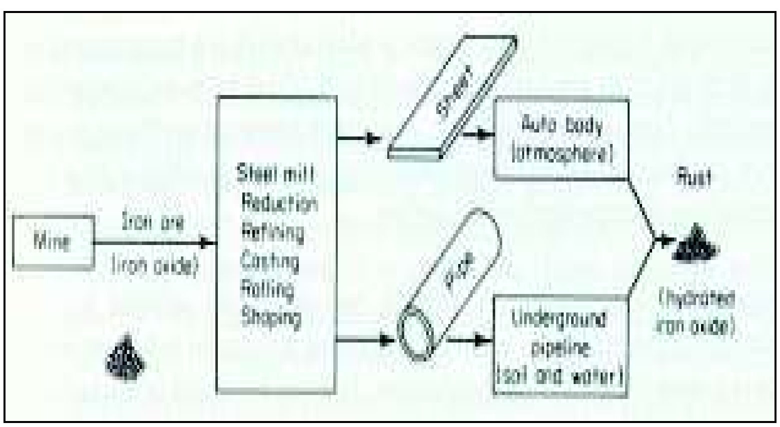

Figure 2.1: Metallurgy in reverse

Source: Mars G. Fontana 1986

2.2 Definition of corrosion

Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment. Some insist the definition should be restricted to metals but often the corrosion engineers must be consider both metals and nonmetals for solution of a given problem. Corrosion can be fast or slow. For example the sensitized 18-8 stainless steel is badly attacked in hours by polythionic acid and the railroad tracked usually show slight rusting not sufficient to affect their performance over many years.

Corrosion of metals could be considered as extractive metallurgy in reverse as illustrated by Figure 2.2. Extractive metallurgy is concerned primarily with the winning of the metal from the ore and refining or alloying the metal for use. Most iron ores contain oxides of iron and rusting of steel by water and oxygen results in a hydrated iron oxide. Rusting is a term reserved for steel and iron corrosion although many other metals form their oxides when corrosion occurs. (Mars G. Fontana, 1986)

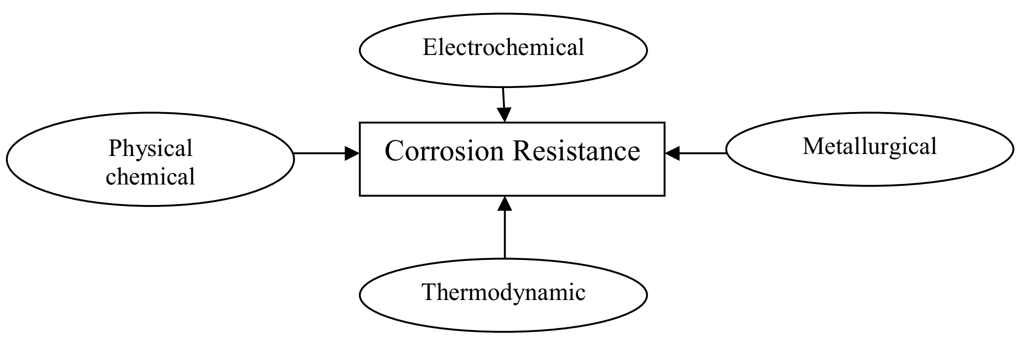

Figure 2.2: Factor affecting corrosion resistance of a metal

Source: Mars G. Fontana 1986

2.3 Factors influencing corrosion reactions

Mechanism of a chemical reaction it is advisable to separate the factors which determine the tendency or driving force of the reaction to proceed from those which influence the rate of the reaction made possible by the existence of this tendency. This tendency is an expression of the fact that the system is not in a state of equilibrium or inherent stability. It is measured by the difference in energy between the initial and final state of the system for any particular case. In most cases the observed rate is determined not by the absolute magnitude of this tendency but by other factors which depend primarily upon the environment.

In considering the group of three typical reactions involved in corrosion, it shall denote as primary factors those which determine the tendency of the metal to corrode and thus influence its initial rate of solution and as secondary factors those which influence the rate of the subsequent reactions. This term in no wise implies that these secondary factors are of lesser importance. In fact, by influencing the nature and distribution of the final corrosion products, they usually determine the ultimate rate of corrosion and the useful life of the metal in each environment.

In the general case, some one or two of the many factors involved exert outstanding influence upon the ultimate rate of corrosion in term of controlling or dominant factors. In general, the primary factors have to do with the metal or alloy itself. The secondary factors more with the specific environment. It is convenient to divide them in this way, although no sharp distinction can be made. (Frank N. Speller, 1926).

2.4 Mechanism of corrosion

Corrosion of metals takes place through the action of electrochemical cells. Although this single mechanism is responsible, the corrosion can take many forms. Through an understanding of the electrochemical cell and how it can act to cause the various forms of corrosion, the natural tendency of metals to corrode can be overcome and equipment that is resistant to failure by corrosion can be designed. (NAVFAC, 1992)

2.4.1 The Electrochemical Cell

As in all chemical reactions, corrosion reactions occur through an exchange of electrons. In electrochemical reactions, the electrons are produced by a chemical reaction, the oxidation, in one area, the anode and travel through a metallic path and are consumed through a different chemical reaction in another area, the cathode. In some cases, such as the common dry cell battery, electrochemical reactions can be used to supply useful amounts of electrical current. In marine corrosion, however, the most common result is the transformation of complex and expensive equipment to useless junk. In order for electrochemical reactions to occur, four components must be present and active. These components are the anode, cathode, electron path, and electrolyte. (NAVFAC, 1992)

(i) Anode

In an electrochemical cell, the anode is the site where electrons are produced through the chemical activity of the metal. The anode is the area where metal loss occurs. The metal loses electrons and migrates from the metal surface through the environment. The electrons remain in the metal but are free to move about in response to voltage gradients. (NAVFAC, 1992)

(ii) Cathode

The cathode in an electrochemical cell is the site where electrons are consumed. For each electron that is produced at an anodic site, an electron must be consumed at a cathodic site. No metal loss occurs at sites that are totally cathodic. (NAVFAC, 1992)

(iii) Electron Path.

In order for electrons to flow from the anodic sites to cathodic sites, the electrons migrate through a metallic path. This migration occurs due to a voltage difference between the anodic and cathodic reactions. Electrons can move easily only through metals and some non-metals such as graphite. Electrons from electrochemical reactions cannot move through insulating materials such as most plastics nor can they directly enter water or air. In some cases, the electron path is the corroding metal itself, in other cases the electron path is through an external electrical path. (NAVFAC, 1992)